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Sustainability of Roof Water Harvesting Structure on Hillock in North East of India

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Abstract: **Rainwater harvesting systems are very useful in mainly hilly region, urban area and deserted area. In North East of India, most of the area of Assam is dominated by hillock and receives average annual rainfall of 2349.46 mm in 220 rainy days. Though the rainfall is abundant in Assam but due to lack of adequate storage facilities, and the absence of effective delivery systems, many small villages also face severe constraints in terms of both the lack of water and excess of water during the rainy season. So, present study was carried out to study the sustainability of Roof water Harvesting Structure (RHS) for garden plants on hillock at the Department of Agricultural Engineering, Assam University Silchar, India. In the present study, one Low Density Poly-Ethylene (LDPE) lined RHS of storage capacity 26500 L (≈26.5m^3) was developed and it's the dimensions used to compute the volume water balance and reliability analysis for four water demand 300, 400 and 500L/day. The results of water balance and reliability study reveals that at the end of the year (365th day), the available storage volume for the demand 200, 300, 450 and 500 L/day were 22445.59, 19345.59, and 14695.59, 13145.59 L, respectively. The available storage at the end of the year for the demand of 500L/day was found less than 14500 L which reduced to zero on 27th day of January of the next year (392nd day). So, the RHS was found infeasible for the demand of 500L/day. However, demand 450 L per day was fulfilled round the year without shortage of supply. Hence, demand of 450 L/day was found as the optimum which could meet round the year from the developed RHS and based on which the number of garden plants could be grown.**

1. INTRODUCTION

Rainwater harvesting is an ancient technology that has been used throughout history to supply water to human settlements and, more recently, to buildings in urbanized areas [4]. Globally, millions of systems are currently in use [5, 7] and a wide variety of both potable and non-potable applications are evident [1, 2 3, 4, 6, 8, 9, 10, 11].

In Assam, even where rainfall is abundant, the lack of adequate storage facilities, and the absence of effective delivery systems, many small villages also face severe constraints in terms of both the lack of water and excess of water during the rainy session this is due to the shortage of rainwater harvesting structure and drainage system. Due to undulating topography with steep slope and high percolation, the rainwater might not possible to harvest and retain for a long time in Hillock. So, rain water harvesting using lining material is the only alternative to harvest the direct rainfall and roof water for non-portable use. Thus, in the present study a polyethylene lined roof water harvesting structure has been developed on hillocks at the Department of Agricultural Engineering, Assam University, Silchar, Assam for reliability analysis of storage capacity under different water demand scenarios of garden plants using a daily water balance model.

2. MATERIALS AND METHODS

2.1. Study Area

One of the Hillocks present at the Assam University Campus which is situated in the southern part of the Indian state of Assam is considered for the study site (Figure 1). The geographical position of Assam University, Silchar is 24.6916º N and 92.7512º E. Soils of the zone vary from sandy type to clay soil mostly suitable for field crops including horticultural crops. The soil pH ranges from 4.6 to 5.7. The climate of Assam is characterized by its extreme humidity. The neighborhood of Cherrapunji and Mawsynram are known to receive the highest rainfall in the whole world. Silcoorie raingauge station is the nearest raingauge station from Assam University. Silcoorie Raingauge Station receives an average annual rainfall of 2334 mm.

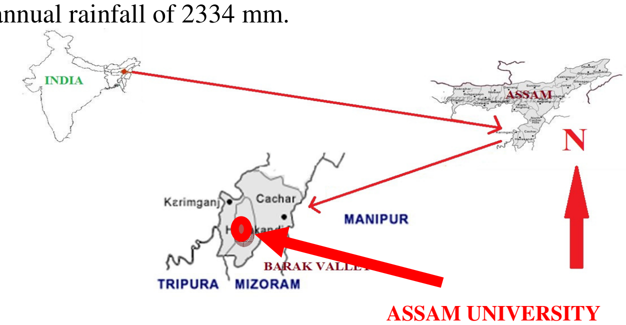

Fig. 1. Location of the study area.

2.1 Roof water harvesting system (RHS)

All rainwater harvesting systems share a number of common components such as (i) a catchment surface from which runoff is collected, e.g. a roof surface. (ii) a system for transporting water from the catchment surface to a storage reservoir (conduits/lined channel). (iii) a reservoir where water is stored until needed (water harvesting structure). (iv) a device for extracting water from the reservoir (irrigation system).

The RCC building of the Agricultural Engineering Department is located at hillock and it has three blocks such as east, west and north block with different heights. The experimental fields are available in eastern side of the department and in other side the space is very less for construction of harvesting structure. So, the eastern roof of the department was selected for catchment and harvesting structure for garden use. Schematic diagram of roof water harvesting system is shown in Figure 2.

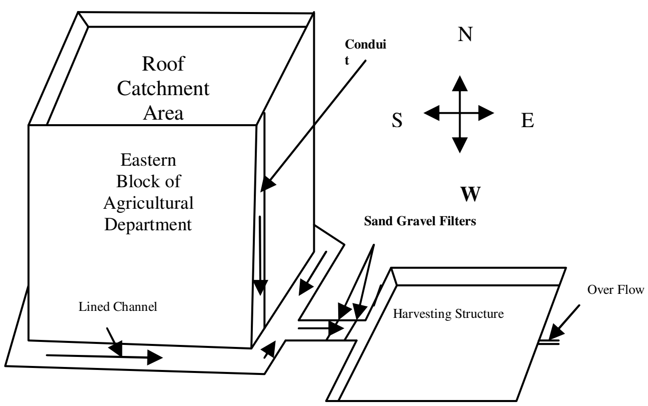

Fig. 2. Schematic diagram of roof water harvesting system.

Seepage and percolation are the major losses in a rainwater harvesting structure (RHS) on a hillock. Hence, lining of the harvesting structure is essential to check the losses. Considering the cost effective of the lining materials, low density poly ethylene (LDPE) sheet of 120 GSM was selected for the present study. LDPE sheets, as per 2012 schedule rate was Rs. 60 m^{-2}. The polythene is flexible, light weight, Swiss Technology, U.V. stabilised, and heat sealed joint and 100% waterproof.

The harvesting structure was constructed in stepwise pattern to increase the life of the LDPE sheet by covering the soil on it and also to prevent the exposure of the lining material to sunlight with getting. The required size of the LDPE sheet was estimated based on the water demand for garden plants. Then, the agrifilm (120 GSM) was laid properly on the pond. Soil cover of 30 cm is provided over the agrifilm (Figure 3). Size of the polythene is (10.80×8.66) m, flexible, light weight, Swiss technology, U.V. stabilised, and heat sealed joint and 100% waterproof. The surface area of the rainwater harvesting structure is 24.75 m^2. The over flow pipe of 100 mm diameter was also attached for removing the excess water from the harvesting structure.

Fig. 3. Stepwise construction and lining of RHS.

A spreadsheet based on a daily water balance model was developed considering daily rainfall, contributing catchment (roof) area, losses due to leakage, evaporation, storage (tank) volume and water uses. The daily runoff volume was calculated from the daily rainfall amount by multiplying the rainfall amount with the contributing roof area and runoff co-efficient.

Available storage capacity was compared with the accumulated daily runoff. If accumulated runoff is higher than available storage volume, excess water is flow out through over flow pipe. Then the amount of water uses is deducted from the daily accumulated.

The RHS used in the present study was rectangular in shaped dug out ponds below field level. Side slope of the RHS was expressed as horizontal: vertical. Height, top width, and bottom width, side slope of the embankment of the RHS are 2, 4.5, 1.5 m, and 1:1, respectively. Figure 4 represents the cross section and dimensions of the RHS used for the experimental study.

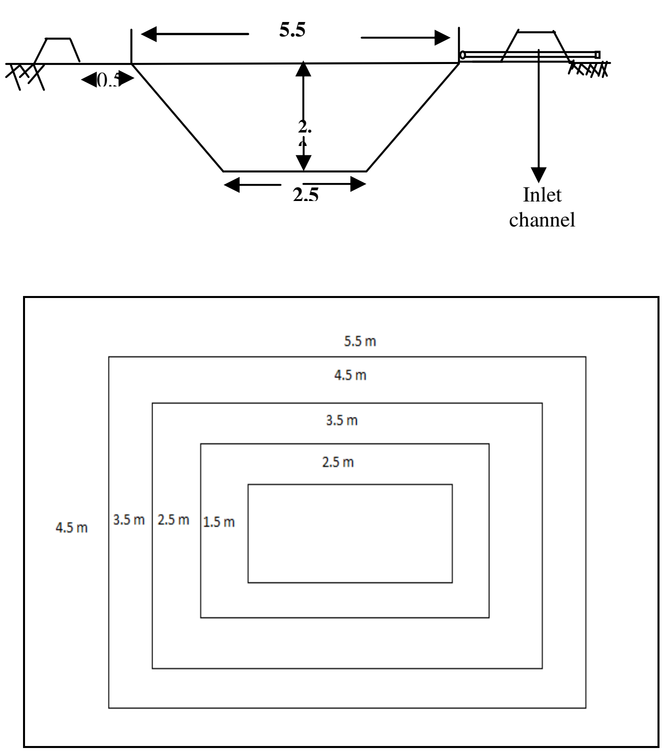

Fig. 4. Cross section and dimensions of the RHS.

Table 1: Daily water (litres) consumption in a small Garden for different region.

Region	Grass and Fruit Trees	Flowers and Vegetables	Bushes and Ornamental Trees	Grass	Flowers and Vegetables	Bushes
Coastal strip	3.0	4.5	1.5	2.0	3.0	1.0
Coastal plain	3.5	5.0	1.5	2.5	3.0	1.0
Mountains	4.0	6.0	2.0	3.0	4.5	1.5
Negev and hot valleys	4.5	6.5	2.0	3.0	4.5	1.5
Arava and eilat	7.0	11.0	3.5	5.0	8.0	2.5

(Source: Ministry of agriculture, www.moag.gov.il)

The storage tank is 5.5 m in length and 4.5 m breadth on the top surface and depth of each step is 0.5 m. It has four steps each steps having 0.5m in depth and 0.5m in breath on downward. The volume of the storage structure is 26.5 m³.

2.2 Reliability analysis

Water requirement for a garden is differenced from plant to plant and regions. As per the recommendation of Ministry of Agriculture, (www.moag.gov.il) given in Table 1, the daily consumption of garden plant varies from 1.5 to 6 litres in a mountainous region. So, in the present study the garden plants (ornamental plants of 100 numbers) with water consumption @ 2L/day were considered for the design and development of RHS. The feasibility of the RHS for other consumption 300, 450 and 500 L/day also analyzed from the developed RHS.

3. RESULTS AND DISCUSSION

3.1 Volume Water Balance of RHS

In the region, an individual house of average area of 300-500 m^2 has been used for dwelling. So, in the present study, roof catchment surface is 380.47 m^2 was considered for estimating the volume of runoff generated from roof top and further analysis. A meteorological observatory located at Silcoorie is the nearest station from the study area. So, the rainfall and evaporation data are collected on daily basis from the Silcoorie observatory station. Based on the availability, the meteorological information (rainfall, evaporation) on daily basis for ten years (2003 to 2012) were collected and used for analysis.

Considering only the 100 numbers of garden plants with daily requirement is on 2L/each plant (Ministry of Agriculture), the initial volume water balance of RHS was estimated. The daily variations of water balance volume round the year 2012 are shown in Figure 2.

It was found from the volume water balance variations that volume was less than 600 L for initially 45 days and then the volume has been increased gradually to 26500 L on 91st day of the year. It was also observed that RHS was remained full from 91st to 302nd day of the year where excess runoff was overflow from the RHS. So, there are excess volume of water could be harvesting to fulfil the more water demand.

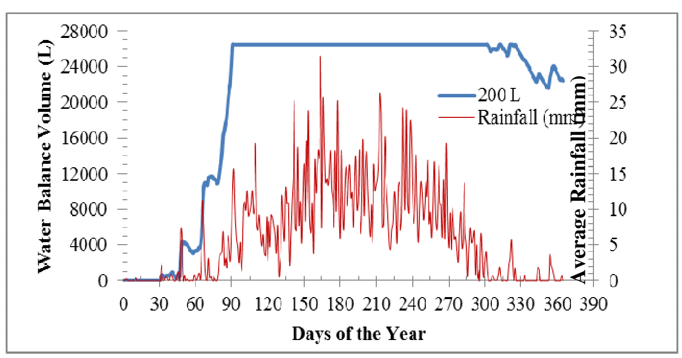

Fig. 2. Daily variations of rainfall and water balance volume in RHS round the year.

Since, storage in the RHS was found 22445L on 365th day of a year. So, the available storage could meet sufficiently the water requirement during initial 45 days (dry period) in next year also. Moreover, to know the hydro-economic reliability of the existing RHS for different water demand further analysis could be made for efficient utilisation of harvested roof water.

3.2 Sustainability of RHS

Since, water balance analysis of the developed RHS was sufficed the water demand of 200 L/day throughout the year and in near future there might be policy for either increasing the number of garden plants or water demand based on age of plants. So, the reliability analysis was carried out to find out the maximum demand could be met round to the year from the developed RHS in the study area. In addition to the initial demand (200L/day), other volumes of demand considered for water balance analysis were 300, 400 and 500L/day. The daily variation water balance volume for different water demands are shown in Figure 3.

It was observed that the available RHS storage could meet the water demand of 300 and 400 L/day but could not fulfil the demand of 500L/day round the year. So, demand 450L/day was introduced to find out the status round the year. At the end of the year (365th day), the available storage volume for the demand 200, 300, 450 and 500 L/day were 22445.59, 19345.59, and 14695.59, 13145.59 L, respectively. The available storage at the end of the year was found less than 14500 L and also observed that storage volume reduced to zero on 27th day of January of the next year (392nd day). There are 60 more days of dry period. So, the demand of 500L/day could not meet from the existing RHS after.

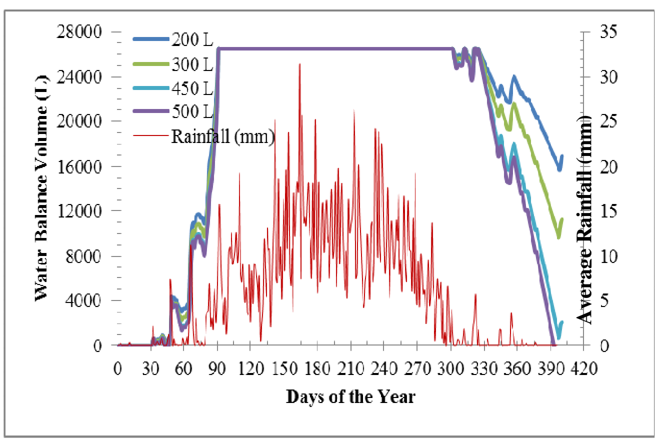

Fig. 3. Daily variations of rainfall and water balance volume in RHS round the year for demand of 200, 300, 450 and 500 L/day.

However, demand 450 L per day was fulfilled round the year without shortage of supply. Hence demand of 450 L/day was found as the optimum which could meet round the year from the developed RHS. It means the developed RHS could supply water for total 225 garden ornamental plants in departmental garden. Further the fluctuation of estimated water volume could be compared with the observed date. Hence, demand of 450 L/day was found as the optimum which could meet round the year from the developed RHS. It means the developed RHS could supply water for total 225 garden ornamental plants in departmental garden. Further the fluctuation of estimated water volume could be compared with the observed date.

4. CONCLUSIONS

The study area is dominated by hillock and receives average annual rainfall and roof top runoff of 2349.46 mm and 1997.04 mm, in 220 rainy days, respectively. So, the development of lined (LDPE of 120 GSM) RHS of 26500 L (≈26.5m^3) was found hydrologically feasible to supplement the requirement during dry months (145 days only). The reliability analysis for different demands revealed that maximum demand of 450 L per day could be fulfilled round the year without deficit.

Roof rainwater harvesting requires low cost, less effort for collection and storage of water. Rain and/ or roof water harvesting system is very useful in hillock area because it is the most efficient way of conservation of water in such places.

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